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Analysis of 121 fatal passenger car-adult pedestrian accidents in China

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A B S T R A C T

To study the characteristics of fatal vehicle-pedestrian accidents in China , a team was established and passenger car-pedestrian crash cases occurring between 2006 and 2011 in Beijing and Chongqing, China were collected. A total of 121 fatal passenger car-adult pedestrian collisions were sampled and analyzed. The pedestrian injuries were scored according to Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS). The demographical distributions of fatal pedestrian accidents differed from other pedestrian accidents. Among the victims, no significant discrepancy in the distribution of ISS and AIS in head, thorax, abdomen, and extremities by pedestrian age was found, while pedestrian behaviors prior to the crashes may affect the ISS. The distributions of AIS in head, thorax, and abdomen among the fatalities did not show any association with impact speeds or vehicle types, whereas there was a strong relationship between the ISS and impact speeds. Whether pedestrians died in the accident field or not was not associated with the ISS or AIS. The present results may be useful for not only forensic experts but also vehicle safety researchers. More investigations regarding fatal pedestrian accidents need be conducted in great detail.

1. Introduction

With the rise in global urbanization and motorization, road traffic accidents (RTAs) induced injuries have become major worldwide public health problems. According to a report by World Health Organization,[1] over 1.2 million people died from RTAs each year in the world and about 50 million were injured. It was predicated that the injuries related to RTAs will rise to become the fifth leading cause of death by 2030.[1] Pedestrians, as one of the most vulnerable road users, are accounted for a very high proportion of fatalities involved in RTAs around the world. For example, in the developed countries with high incomes, typically 10–30% of fatalities related to RTAs are pedestrians. Meanwhile, substantially higher pedestrian fatal proportions were reported in the other countries with middle or low-incomes, despite the figures are underestimated.[1]

For experts in forensic medicine, the analysis of causes of injuries or deaths from RTAs has become a very important part of their daily work.[2–4] Few studies have been performed to investigate the characters of fatal pedestrian accidents, especially for the middle and low income countries, e.g. China, although fatal pedestrian accidents occur very frequently in these countries.[1] It has been suggested that pedestrian injuries can provide evidential value for reconstruction of pedestrian-vehicle accidents at the moment of collision,[5] and that pedestrian injuries maybe a further evaluation index to reconstruct car-to-pedestrian collision.[6] In the authors' point of view, the injuries sustained by the pedestrians need to be studied in detail from fatal vehicle-pedestrian collisions to reconstruct the collisions.

To date, a large number of pedestrian accidents have been investigated worldwide, especially for some developed countries. It has been accepted that real-world vehicle-pedestrian collision data may provide first-hand information about patterns, causation, risk factors of accidents, and valuable background for decreasing pedestrian injuries and deaths.[7] The data are important not only to legal medical experts to validate the vehicle-pedestrian crash reconstruction, but also to researchers to develop the techniques to reduce or prevent such crashes.[8] However, limited research was focused on fatal vehicle-pedestrian accidents in the countries with middle or low incomes.

Nowadays, pedestrian accident databases with detailed information related to crashes and injuries are available for a small

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number of developed countries. Such databases include the International Harmonization Research Activity (IHRA) dataset in Japan,[9] the German In-Depth Accident Study (GIDAS),[10] the United States Pedestrian Crash Data Study (PCDS),[11] and the Australian database.[12] There is still a great demand for accident data from developing countries because of their unique circumstances, e.g. lack of comprehensive, well-documented dataset, as well as difficulty accessing existing data,[13] although some investigations regarding pedestrian-accident crashes have been performed from the collected in-depth vehicle-pedestrian data at a regional level in China.[14,15] As an extension of these studies, this paper aims to address the characters of fatal pedestrian accidents by analyzing a large number of recent fatal vehicle-pedestrian crashes in multi areas.

2. Methods

A team, consisting of engineers and medical experts, has been found since 2006 in the Institute of Surgery, Third Military Medical University, Chongqing, China. The team, cooperating with police departments, collected onsite passenger car-pedestrian accident cases occurring between 2006 and 2011 in Beijing, Northern China, which are characterized by a flat area, and Chongqing, Southern China, which is characterized by mountainous regions. The accident-related information included the data of human, environmental, and vehicular factors.

Human information contained the pedestrian age, gender, injury outcome, injured body region, injury severity, person's action prior to the crash, with treatment or not, and surviving time. The age were classified as Group 1 (aged 16–25), Group 2 (aged 26–45), Group 3 (aged 46–60), and Group 4 (over 60 years). Pedestrian injuries within a specific body region or anatomical structure were scored according to 'The Abbreviated Injury Scale 2005 (AIS 2005) Revision' by the Association for the Advanced of Automotive Medicine,[16] from AIS 1 (minor), AIS 2 (moderate), AIS 3 (serious), AIS 4 (severe), AIS 5 (critical) to AIS 6 (currently untreatable). The Injury Severity Score (ISS) was calculated by summing the squares of the AIS codes of the three most severely injured body regions. Cases were grouped into three categories according to ISS values: 0-14, 16-66, and 75, representing minor, major, and incompatible-with-life injuries, respectively. Person's actions prior to the crashes were divided into standing still, crossing the road, and walking along the road.

Environmental factors included weather condition (Sunny, Others) and road types (Urban road, Highways, Others). The passenger cars enrolled in the study were classified as Sedan, sport utility vehicle (SUV), and 1-Box based on the front shape: (1) Bonnet Leading Edge (BLE) < 835 mm, Sedan; (2) BLE > 835 mm, SUV; (3) Bonnet angle $\geq 30^0$, 1-Box.[17,18]

The vehicle impact speed, v (unit: km/h), was derived from the braking distance[19] if the vehicle braking marks could be identified, where a is the deceleration (unit: m/s^2) and s is the braking skid distance (unit: m).

$$v = \sqrt{2as} \times 3.6 \tag{1}$$

or it was calculated from the pedestrian throwing distance,[1915]

$$v = \sqrt{2g} \times \varphi \times \left(\sqrt{h + \frac{x}{\varphi}} - \sqrt{h}\right) \times 3.6 \tag{2}$$

where φ is the friction coefficient between the pedestrian and road, x represents the pedestrian throwing distance (unit: m) and h means the height of the pedestrian's center of gravity (unit: m).

The accidents in which the pedestrians died within 7 days as a direct result of vehicle impact were sampled, and accidents in which the impact speed could not be estimated from either braking skid marks or pedestrian throwing distance were not considered in this study. The accidents enrolling pediatric pedestrians were excluded owing to the possible differences in the mechanism and/or injury patterns as compared with adults. Additionally, accidents in which a car collided with more than one pedestrian or one pedestrian sustained multi-vehicles collisions or run-over were not enrolled.

The associations between pedestrian injuries and personal, vehicular, and environmental factors were investigated via χ^2 test. The relative likelihood of pedestrians died in the field versus survived was analyzed from variables with environmental, human, and vehicle factors. Data were processed, by using software SPSS® 11.0 (SPSS Inc, Chicago, IL). The values, $p < 0.05$, were considered statistically significant.

3. Results

A total of 121 fatal passenger car-pedestrian crashes meeting the inclusion criteria were chosen. Among the sampled accidents, 26 (21%) cases occurred in Beijing, and 95 (79%) in Chongqing. For the accidents, 108 (89%) occurred under nice weather conditions, and 83 (69%) occurred in urban roads, while 34 (28%) in highway. It was shown that 29% of fatal pedestrian accidents occurred in highways in Chongqing, which have a higher probability than those in Beijing ($p = 0.021$), as exhibited in Fig. 1.

Of the vehicles involved in the crashes, there were 87 (72%) sedans, 20 (17%) 1-box vehicles, and 14 (12%) SUVs. For the vehicles involved in the crashes, the impact speeds varied from 23 km/h to 128 km/h, with an average speed of 64.1 ± 21.6 km/h Fig. 2 plots the distributions of impact speeds of accidents occurring in urban road and highways, in which the mean of impact speeds for the accidents in highway was 82.3 ± 23.8 km/h, higher than that in urban road, 56.7 ± 15.4 km/h ($p = 0.0001$). For the accidents sampled in urban road, 52 (63%) occurred at the impact speeds from 40 km/h to 69 km/h.

Of the killed pedestrians, males were 64 (53%), and females 57 (47%). Among the fatalities, the eldest was 87 years old, and the youngest was 23 years old, with an average age of 56.2 ± 15.0 years old. For the victims, 87 (82%) were crossing the roads prior to the crashes, 28 (23%) walking along the roads, and 6 (5%) standing still in the roads.

Among the killed pedestrians, head, neck, chest, abdomen, extremities, and spine were the common injury localizations. The victims with multiple injuries were up to 102, accounting for 84% of the fatalities. Among the deaths, 119 (98%) sustained head injuries, followed by 74 (61%) extremity injuries, 73 (60%) thorax injuries, and 32 (26%) abdomen injuries. Of the killed pedestrians, 99 (82%) died from head injuries, 36 (30%) from thorax injuries. A total of 32 (26%) pedestrians died in which both head injuries and thorax injuries were the fatal causes. The maximal ISS of the deaths was 75, and the minimal was 4, with an average ISS of 33.7 ± 18.0.

Of the victims, the common injury patterns included laceration, contusion, dislocation, fractures, etc., and the injury severities varied from AIS 1 to AIS 6. Table 1 summarizes the distributions of pedestrian ISS and AIS in head, thorax, abdomen, and extremity by age groups. No significant distribution discrepancy of AIS in pedestrian head, thorax, abdomen, as well as extremities was found by the age, and the ISS difference was not observed in the killed pedestrians by age groups, either, from the table. The data of pedestrian ISS and AIS distributions by pedestrian actions, as shown in Table 2, indicates that pedestrian head AIS distributions were associated significantly with their behaviors prior to the crash ($p < 0.05$). Meanwhile, ISS of pedestrians on crossing the road prior to the crashes was higher than that on standing still ($p < 0.05$).

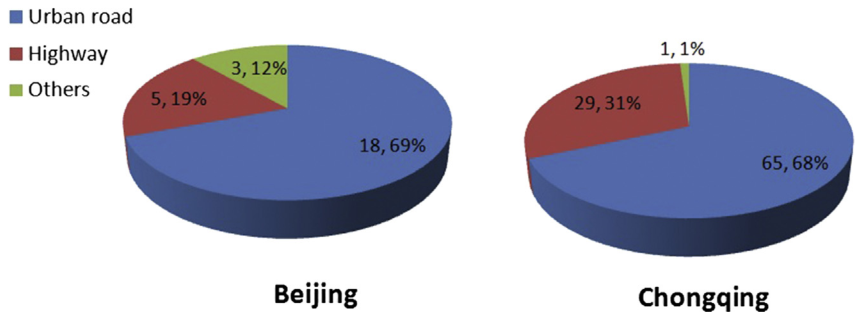

Fig. 1. Distributions of accident field in the sampled areas.

Table 3 demonstrates the ISS and AIS distributions by impact speeds. From the table, it was found that impact speeds were associated significantly with pedestrian AIS distributions of extremities. The pedestrian ISS, moreover, was significantly related to impact speeds. Table 4 shows the distributions of fatal pedestrian ISS and AIS by vehicle types. No distribution difference in pedestrian ISS and AIS by vehicle types was found in the table.

Among the killed pedestrians, 71 (59%) died in the accident field without any treatment, and 38 (31%) died at the survival time of less than 24 h, 12 (10%) at the survival time ranging from 1 day to 7 days. For the victims died in the field, 7 (10%) were minor injuries. Data shown in Table 5 summarizes the relative likelihood of pedestrians died in the field versus not based on person-, vehicle-, and environment-related variables. From the table, it was found that the accidents with the impact speeds of over 70 km/h had an higher risk for pedestrians died in the accident field, compared to those with the impact speeds of lower 40 km/h, and pedestrians involved in crashes in highways had higher proportions to die in the accident field than those in urban roads. The ISS and the AIS in head, thorax, abdomen, and extremity, were not related to the pedestrian survival or death in the accident field according to the data.

4. Discussion

Pedestrians accounted for a substantial portion of the overall road traffic injuries, and the high portion of worldwide road user fatalities were pedestrians hit by vehicles.[1] Furthermore, it was proposed that pedestrian injuries and deaths will increase abruptly as the rapid growth of motorization level in some developing countries.[1] Although numerous studies regarding vehicle-pedestrian crashes have been performed to prevent pedestrian injuries from collisions in advanced countries as well as some developing countries,[7,9–15,17,18] it was of particular importance to address some characters concerning fatal passenger-car to pedestrian accidents, especially in the developing countries, such as China.

The demographical distribution of fatal pedestrian accidents in the current study differed from the other previously reported studies. For example, 53% of the fatalities were males in this study, lower than those reported previously by Chen et al.[17] and Zhao et al.[15] The previous data of Milliscent et al.[20] showed that the ratio of deaths of males to females was 3.3 in four South African cities. Richard et al.[21] concluded that males had the 50% higher rate than females by performing a retrospective analysis of 217 pedestrian traffic fatalities in Seattle, WA, U.S.A. Kanchan et al.[4] reported, from the 879 victims induced by TRAs in South India, that the mean age was slightly higher in females compared with that in males. Our previous results showed that pedestrian gender was not associated with pedestrian survival or death.[18]

Jonathon et al.[22] studied fatal pedestrian crashes in American Indians and Alaskan Natives, and found rural pedestrian crashes occurred more frequently in highways ($p < 0.0001$) owing to lacking traffic control devices ($p < 0.0001$) and artificial lighting ($p < 0.0001$). Highways have been closed in general by building the barriers along the sides, and pedestrians are prohibited entering into highways in China. In the current study, however, there were a large number of pedestrians involved in fatal collisions in highways. The reported results by Arora et al.[2] showed that most of the accidents causing pedestrian deaths occurred straight roads instead

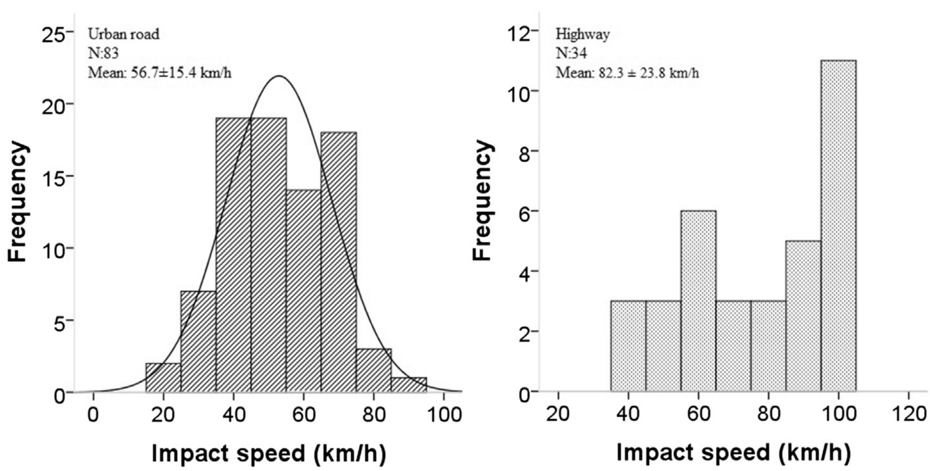

Fig. 2. Distributions of impact speeds in urban roads and highway.

Table 1
Distributions of pedestrian ISS and AIS by age groups.

Age group	121	Head (AIS)(119)			Extremities (AIS)(74)			Thorax (AIS)(73)			Abdomen (AIS)(32)			ISS
		1-2(5)	3-4(61)	5-6(53)	1-2(47)	3-4(27)	5-6(0)	1-2(12)	3-4(60)	5-6(1)	1-2(11)	3-4(21)	5-6(0)	
Group 1	2(2%)	0(0%)	1(2%)	1(2%)	1(2%)	1(4%)	0(0%)	0(0%)	1(2%)	0(0%)	0(0%)	1(5%)	0(0%)	23.5 ± 2.1
Group 2	25(21%)	0(0%)	11(18%)	13(25%)	7(15%)	7(26%)	0(0%)	3(25%)	8(13%)	0(0%)	3(27%)	3(14)	0(0%)	34.7 ± 18.4
Group 3	48(40%)	4(80%)	25(41%)	19(36%)	20(43%)	8(30%)	0(0%)	5(42%)	29(48%)	1(100%)	5(45%)	8(38%)	0(0%)	35.4 ± 19.2
Group 4	46(28%)	1(20%)	24(39%)	30(57%)	19(40%)	11(41%)	0(0%)	4(33%)	22(37%)	0(0%)	3(27%)	9(43%)	0(0%)	31.9 ± 16.8

Table 2
Distributions of pedestrian ISS and AIS by pedestrian actions prior to crashes.

Pedestrian actions	121	Head (AIS)^			Extremities (AIS)			Thorax (AIS)(0.063)			Abdomen (AIS)			ISS
		1-2(5)	3-4(61)	5-6(53)	1-2(47)	3-4(27)	5-6(0)	1-2(12)	3-4(60)	5-6(1)	1-2(11)	3-4(21)	5-6(0)	
Standing still	6(5%)	1(20%)	2(3%)	2(4%)	4(9%)	1(4%)	0(0%)	0(0%)	1(2%)	0(0%)	0(0%)	1(5%)	0(0%)	20.3 ± 14.6*
Walking along the road	28(23%)	1(20%)	19(31%)	8(15%)	12(26%)	3(11%)	0(0%)	4(33%)	17(28%)	1(100%)	3(27%)	6(29%)	0(0%)	30.1 ± 13.8
Crossing the road	87(72%)	3(60%)	40(66%)	43(81%)	31(66%)	23(85%)	0(0%)	8(67%)	42(70%)	0(0%)	8(73%)	14(67%)	0(0%)	35.5 ± 19.0*

^$p < 0.05$, *$p < 0.05$.

of bends or intersections, and that there were more accidents occurring in daytime and weekend. Similar to other studies of China,[15,17] the present study showed that more pedestrians were involved in fatal crashes under nice weather conditions.

The older people are considered generally more fragile than the younger, which means they tend to sustain more severe injuries for a given level of impact loading.[7,23–25] The report by Kim et al.[26] estimated the probability of fatal-injury per crash as a function of pedestrian age, in which senior pedestrian with over 80 years old had a significantly higher probability to sustain fatal injuries. In the current study, the senior pedestrian (over 60 years) accounted for about 38%, higher than that of IHRA.[9] Richard et al.,[21] analyzing 217 pedestrian traffic fatalities, found that head injuries were much less common in the oldest age group, and considered elderly pedestrians were more vulnerable to death from less severe trunk and extremity injuries. Our previous study showed that pedestrian victims over 60 years of age were almost four times more likely to suffer a head injury relative to younger victims.[18] However, among the victims, significant statistical discrepancy of ISS and AIS in the injured body regions by the age has not been found from the data in Table 1.

In the current study, it was shown that the highest proportion of pedestrians (82%) died of head injuries, followed by thorax injuries (30%). Richard et al.[21] thought severe chest injury was the most important predictor of death occurring at the scene. In their results, the fatal head injuries and severe chest injuries were reported in 73% of cases, and the injuries involving multiple sites were reported in 60%. It was found, in the current study, that among the pedestrians, 102 (84%) suffered multiple injuries, and 32 (26%) died as the results of both head and thorax injuries.

Consistent with some previously reported results,[9,15,17,27] the highest proportions of vehicle-pedestrian crashes occurred when pedestrians were crossing the roads in the present study. Furthermore, our data, as shown in Table 2, shows that pedestrians' behaviors prior to the crashes may affect the injury severities. Compared with those standing still, pedestrians crossing the road may sustain more severe head injuries ($p < 0.05$). Additionally, it was considered that there existed some associations between pedestrian age and pedestrian behaviors among the fatal pedestrian accidents.[2,28] Therefore, the authors suggested here that pedestrian behaviors should be concerned in reconstructing and analyzing fatal pedestrian accidents.

Vehicle impact speed is one of the most predominant factors on the pedestrian fatal risk in the collision accidents. Fatal pedestrian crashes could occur with the probability of 40–90% at an impact speed of 50 km/h due to different sampling methods and areas.[29] It was found in the current study that the accidents occurring in highways had higher impact speeds, as compared with those in urban roads. In urban roads, more than one half of the fatal crashes occurred at the impact speeds within 40–69 km/h.

Table 3
Distributions of pedestrian ISS and AIS by impact speeds.

Impact speeds(km/h)	121	Head (AIS)			Extremities* (AIS)			Thorax (AIS)			Abdomen (AIS)			ISS
		1-2(5)	3-4(61)	5-6(53)	1-2(47)	3-4(27)	5-6(0)	1-2(12)	3-4(60)	5-6(1)	1-2(11)	3-4(21)	5-6(0)	
0–39	10(8%)	0(0%)	7(11%)	3(6%)	1(2%)	2(7%)	0(0%)	1(8%)	2(3%)	0(0%)	1(9%)	0(0%)	0(0%)	21.0 ± 10.7*^
40-69	65(54%)	2(40%)	38(62%)	25(47%)	29(62%)	10(37%)	0(0%)	6(50%)	29(48%)	0(0%)	7(63%)	8(38%)	0(0%)	31.4 ± 15.8*~
>70	46(38%)	3(60%)	16(26%)	25(47%)	17(36%)	15(56%)	0(0%)	5(42%)	29(48%)	1(100%)	3(27%)	13(62%)	0(0%)	39.9 ± 20.0~^

*: $p < 0.05$, ~: $p < 0.05$,^$p < 0.01$.

Table 4
Distributions of pedestrian ISS and AIS by vehicle types.

Vehicle types	121	Head (AIS)			Extremities (AIS)			Thorax (AIS)			Abdomen (AIS)			ISS
		1-2(5)	3-4(61)	5-6(53)	1-2(47)	3-4(27)	5-6(0)	1-2(12)	3-4(60)	5-6(1)	1-2(11)	3-4(21)	5-6(0)	
1-box	20(%)	0(0%)	10(16%)	10(19%)	9(19%)	1(4%)	0(0%)	0(0%)	12(20%)	0(0%)	1(9%)	3(14%)	0(0%)	33.5 ± 16.3
SUV	14(%)	0(0%)	8(13%)	5(9%)	5(9%)	2(7%)	0(0%)	1(8%)	9(15%)	0(0%)	1(9%)	3(14%)	0(0%)	36.7 ± 19.2
Sedan	87(%)	5(100%)	43(70%)	38(72%)	33(70%)	24(89%)	0(0%)	11(92%)	39(65%)	1(100%)	9(81%)	15(71%)	0(0%)	33.3 ± 18.3

Table 5
Results of multivariate analysis on pedestrians died in accident fields versus not in accident fields.

Risk factor	Unadjusted OR (95% CI)	Adjusted OR
Gender		
Male	1.0(ref)	1.0(ref)
Female	0.72(0.35,1.48)	1.12(0.43,2.95)
Age		
16-25	1.0(ref)	1.0(ref)
26-45	1.42(0.84,24.2)	0.16(0.0,9.05)
46-60	0.67(0.24,1.86)	0.48(0.01,27.2)
>60	1.20(0.53,2.72)	0.25(0.01,13.3)
Person's action		
Standing still	1.0(ref)	1.0(ref)
Walking along road	1.42(0.27,7.42)	0.45(0.03,6.05)
Crossing road	0.92(0.38,2.19)	0.43(0.04,4.56)
Vehicle type		
1-box	1.0(ref)	1.0(ref)
SUV	1.33(0.34,5.27)	2.42(0.39,15.1)
Sedan	0.58(0.22,1.55)	1.0(0.29,3.48)
Impact speed		
0-39	1.0(ref)	1.0(ref)
40-69	0.26(0.05,1.31)	0.17(0.02,1.37)
>70	0.06(0.01,0.34)	0.04(0.0,0.42)
Road Type		
Highways	1.0(ref)	1.0(ref)
Urban road	5.94(2.10,16.8)	3.87(1.06,14.2)
Others	17.4(1.50,202)	7.87(0.41,153)
Weather conditions		
Sunny	1.0(ref)	1.0(ref)
Others	1.76(0.56,5.61)	1.85(0.40,8.60)
ISS		
0-14	1.0(ref)	1.0(ref)
16-66	8.57(0.83,89.0)	4.51(0.52,39.4)
75	10.2(1.27,81.2)	0.79(0.03,21.5)
Head injury(AIS)		
0-2	1.0(ref)	1.0(ref)
3-4	1.59(0.32,7.90)	0.48(0.03,7.03)
5-6	2.05(0.95,4.40)	0.39(0.03,6.21)
Thorax injury(AIS)		
0-2	1.0(ref)	1.0(ref)
3-4	1.0(0.48,2.07)	1.44(0.51,4.10)
5-6	–	–
Abdomen injury(AIS)		
0-2	1.0(ref)	1.0(ref)
3-4	0.85(0.32,2.33)	0.92(0.24,3.50)
5-6	–	–
Extremity injury(AIS)		
0-2	1.0(ref)	1.0(ref)
3-4	0.97(0.41,2.32)	2.26(0.64,7.91)
5-6	–	–

In the present study, pedestrian ISS showed a strong association with impact speeds ($p < 0.01$). Although the strong correlation between impact speeds and pedestrian injury risk has been addressed from previously published crash data, the absolute pedestrian injury risk as a function of impact speed is still controversial due to the bias of accident sampling.[30] In the report of IHRA,[9] head injury distributions of AIS 3-6 and AIS 4-6 were found almost identical, and leg injuries were affected less by impact speeds than head injuries. In the present study, pedestrian AIS of extremities showed the association with the impact speeds, but not for head, thorax, and abdomen. The result of Richard et al.[21] also revealed that a few significant differences in the extent of injuries with respect to vehicle impact speeds were found in the 217 fatal pedestrian fatalities. The primary and secondary injuries did not show a relationship to impact speeds in the results of Karger et al.,[31] while there were some relationships between the occurrence of some injuries and impact speeds.

The pedestrian injury kinematics varied owing to different vehicle frontal structures,[32] which may cause different pedestrian injuries. Kozo et al.[33] pointed out that there was the difference in the patterns and mechanisms by vehicles between flat-front and bonnet-front, and the pedestrians hit by flat-front vehicles tended to sustain more severe injuries at lower impact speeds. Karger et al.[31] concluded that the relationship between vehicle impact speed and characteristic injuries existed only for the cars with a wedge or pontoon shaped front. The previously reported study showed that, given an impact speed, pedestrians are found to have two to three times likelihood of dying, with the substantially greater probability of serious head and thoracic injury, when the striking vehicle is an LTV rather than a car.[34] In the report of Richard et al.,[21] a few significant differences in the extent of injuries with respect to vehicle types were found. Our results, meanwhile, did not show any difference in distributions of pedestrian ISS and AIS by vehicle types among these fatalities, either.

The value of scoring methods like AIS and ISS has been demonstrated not only in accident reconstruction but also in injury prevention.[35] A modification of the ISS, called the New Injury Severity Score (NISS), reported by Osler et al.[36] was more predictive of survival. According to Table 5, it was found that the pedestrian ISS or AIS have not any associations with the ratio of pedestrians died in the field or not, and pedestrians had a high fatal rate of death in the field of accidents with the impact speeds of over 70 km/h or in highways. We found that pedestrians hit in highways died in the field with higher proportions because the rescue organs are far away from the field, also the higher impact speeds, compared with those in urban roads. In the study by Kanchan et al.,[4] it was suggested that the mean duration of survival following road traffic accidents was 6–7 days. In this study, however, it was found that a total of 59% died without any treatments, including some minor injuries. So we agreed that the report of Campobasso et al.[37] that rescue operations in time could do great effects on survival changes in some disaster. However, NISS has not been used to score the pedestrian injuries in this study, because medicolegal document in China record generally the most severe injury in each body region, and some injuries may be neglected.

The fatal pedestrian accidents were analyzed above from pedestrian demographical distributions, pedestrian behaviors, environmental conditions as well as vehicle types. From the results, it could be drawn that some characters of fatal vehicle-pedestrian collisions differed from other vehicle-pedestrian accidents. For forensic experts, this information could play an important role in reconstructing vehicle-pedestrian crashes. On the other hand, analysis of fatal pedestrian accidents in great detail could be useful for some vehicle research experts because a proper understanding of car-pedestrian crashes is critical before developing effective countermeasures aimed at decreasing pedestrian injuries or deaths.[2,31]

5. Limitations

Although some characters of fatal pedestrian accidents from 121 cases in the sampled areas have been analyzed in the present study, some limitations still exist for this study. Compared to 21,106 pedestrian deaths in China in 2007, a total of 121 vehicle-pedestrian crash cases collected from 2006 to 2011 only represented a limited portion. Additionally, fatal accidents in only two areas were collected, which may not represent the national wide China. The number of vehicle-pedestrian accidents occurring in the areas far away from cities could have been underestimated because it was very hard to access detailed accident information onsite. Furthermore, unbalance distribution of rescue organs in sampled areas may result in the bias of results. For example, we found that only 53 pedestrians sustained AIS 5-6 head injuries, which accounted for 44% of killed pedestrians, and about 59% of sampled pedestrians died without any treatment, including some minor injuries. It is

certainly that some killed pedestrians could be saved if the effective rescue measurements could be taken in time. More attention, therefore, should be paid to vehicle-pedestrian crashes using the same method adopted in this investigation to better understand the pedestrian injury problem in China. The authors urged that more studies concerning fatal pedestrian accidents, especially in China, should be carried out in more detail.

6. Conclusion

A total of 121 fatal passenger car-adult pedestrian accidents were sampled and analyzed in the current study. The results showed that the demographical distribution of fatal pedestrian accidents differed from other pedestrian accidents reported previously. On the urban road, 63% of fatal accidents occurred at impact speeds within 40–69 km/h. Among these fatal pedestrians, no discrepancy of ISS and AIS distribution in head, thorax, abdomen, and extremities were found by pedestrian age, while pedestrian behavior may affect pedestrian ISS. Except in extremities, distributions of AIS in head, thorax, and abdomen did not show any association with impact speeds, whereas there was a strong relationship between pedestrian ISS and impact speeds. Pedestrian ISS and AIS in head, thorax, abdomen, and extremities were not related to vehicle types. Meanwhile, the pedestrian died in the accident filed or not were not associated with pedestrian ISS or AIS. The results of the current study may be useful for not only forensic experts but also vehicle safety researchers. We urged that more studies concerning fatal pedestrian accidents in China should be conducted in greater detail.

Ethical approval
None declared.

Funding
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Conflict of interest
None to declare.

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